


Being Underweight Is Associated with Worse Surgical Outcomes of Total Knee Arthroplasty Compared to Normal Body Mass Index in Elderly Patients

This article was published in the following Dove Press journal:
Orthopedic Research and Reviews

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Purpose: Being underweight has never been studied in relation to the radiologic and clinical outcomes of total knee arthroplasty (TKA) in elderly patients. The aim of this study was to determine the effect of being underweight on TKA radiological and clinical outcomes and to investigate whether being underweight influences postoperative complications compared to normal body mass index (BMI) in elderly patients.

Patients and Methods: A total of 118 female patients aged 65 years or older with BMI < 25 kg/m² who underwent primary TKA were divided into two groups based on BMI: group A: 18.5 kg/m² < BMI < 25 kg/m²; group B: BMI < 18.5 kg/m². The radiologic and clinical outcomes were evaluated at follow-up of 6, 12, and 24 months after surgery such as the hip-knee-ankle angle, the American Knee Society (AKS) score, Western Ontario and McMaster University score (WOMAC), and patellofemoral (PF) scale. Moreover, postoperative complications during follow-up were investigated.

Results: Preoperative clinical scores did not differ significantly between the two groups. Postoperative WOMAC pain (1.8 ± 1.9 versus 3.4 ± 2.6 , $p = 0.02$), WOMAC function (12.4 ± 8.1 versus 16.5 ± 8.5 , $p = 0.012$) and PF scales (26.1 ± 3.6 versus 23.7 ± 4.1 , $p = 0.002$) were worse in the underweight group at 12 and 24 months after surgery. The frequency of postoperative complications did not differ significantly between groups. In multivariate linear regression analysis, underweight patient group was significantly associated with worse postoperative WOMAC and PF scores ($p = 0.002$, 0.005).

Conclusion: Although postoperative complications of TKA did not differ between groups, underweight patients had worse clinical outcomes of TKA compared to patients with normal BMI in elderly patients. Therefore, care should be taken when performing TKA in elderly underweight patients.

Keywords: total knee arthroplasty, clinical outcome, body mass index, underweight

Introduction

Obesity is closely related to the development of osteoarthritis and may be one of its main risk factors.¹⁻³ Obesity in TKA patients is associated with poor clinical outcomes and increased early failure rates because obesity increases the mechanical stresses on the implant, as well as reactions by the surrounding bone.^{1,4,5} Since morbidity is related to obesity and increased complications, many orthopedic surgeons are concerned about the poor outcomes of TKA in obese patients.^{3,6-8} Despite

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concerns about the negative effects of obesity on TKA, many studies have found no difference in the clinical outcomes, rehabilitation, complication rate, and survival rate of TKA between obese and non-obese patients.^{9–11} Studies on the effect of BMI on the outcomes of TKA have primarily focused on obesity. However, poor nutritional status and sarcopenia of the quadriceps muscle could also influence the clinical outcomes of TKA, and these variables are closely related to low body mass index (BMI).^{12–14} In many cases, the being underweight in elderly patients is often associated with the patient's frailty, which may indicate a poor quality of life for the patient.¹⁵ Several studies suggested that being underweight in elderly patients could be a predictor of various unhealthy conditions such as undernutrition, worse cognitive status or depression as well as functional disability.^{16–18} Therefore, TKA in elderly underweight patients could have poor surgical outcomes.

BMI is an easy and widely used measurement of obesity that correlates with total body fat.¹⁹ According to World Health Organization (WHO) classification of BMI, obesity is defined as $\text{BMI} \geq 30 \text{ kg/m}^2$, and overweight is defined as $\text{BMI} \geq 25 \text{ kg/m}^2$, and underweight is defined as $\text{BMI} < 18 \text{ kg/m}^2$. In Asia, few patients exhibit Western-style obesity, yet quite a few patients who are normal or underweight have TKA. Nevertheless, studies on the effect of BMI on the outcomes of TKA have so far focused on obesity. Although some studies have shown that being underweight has disadvantages in postoperative anemia and cost in total joint arthroplasty compared to morbid obesity, little has been studied on the effect of being underweight in TKA.²⁰

Therefore, we aimed to determine the effect of being underweight on clinical and radiologic outcomes of TKA and to investigate whether being underweight influences postoperative complications compared to normal BMI in elderly patients. We hypothesized that elderly underweight patients would have poor clinical outcomes of TKA because being underweight might be often associated with poor nutrition status and sarcopenia, indirectly leading to poor clinical outcomes.^{21,22}

Patients and Methods

Patient Recruitment and Study Design

For this retrospective comparative study, we recruited a total of 298 female patients who underwent unilateral TKA between March 2012 and December 2016. We included a total of 118 female patients aged 65 years or older with $\text{BMI} < 25 \text{ kg/m}^2$

who underwent unilateral TKA and completed at least 2 years of follow-up. Patients with lower extremity deformities, such as severe varus or valgus knee deformity more than 15 degrees, and those who required osteotomy together with TKA or special implants, such as varus or valgus constraint, revision surgery, secondary osteoarthritis, or inflammatory osteoarthritis, including rheumatoid arthritis, were not included in this study. All of the recruited patients were women, and the mean age was 70 years (range, 65–84 years). Mean BMI was 22.7 kg/m^2 (range, $17.3\text{--}24.9 \text{ kg/m}^2$). The BMI of patients was calculated based on height and weight measured by an electronic device on the day before surgery. Preoperative serum levels of albumin, hemoglobin, C-reactive protein (CRP), and total cholesterol were investigated and the manual test of quadriceps strength were evaluated. Patients were divided into two groups to compare underweight and normal BMI according to WHO classification of BMI: group A had 77 patients with BMI greater than or equal to 18.5 kg/m^2 and lower than 25 kg/m^2 ; and group B had 41 patients with BMI lower than 18.5 kg/m^2 . We retrospectively reviewed pre- and postoperative clinical information and radiologic findings on the 118 patients who were enrolled in this study, and the differences between the groups were compared. Sample sizes were estimated based on a previous study of patient-report outcomes for total knee arthroplasty in relation to BMI.²³ Using values reported therein, an alpha of 0.05, a statistical power of 90%, and a drop rate of 20%, the sample size of each group was calculated at 30 patients, giving us a number of 60 as a minimum total number of subjects required for this study.

TKA Procedure and Clinical Outcomes

All procedures were performed by a single surgeon using the standard medial patellar approach with tourniquet inflation and the measured resection technique, including selective soft tissue release. A posteriorly stabilized prosthesis (LPS-Flex Gender Knee, Zimmer, Warsaw, IN, USA) was implanted in all patients. The patella was not resurfaced in all cases, and cement fixation was used for all components.

All clinical information was collected using predesigned datasheets in the outpatient clinic pre- and postoperatively and was maintained in our database by an independent investigator. The clinical information included demographic data, preoperative clinical status, and postoperative outcomes. The preoperative clinical status and postoperative outcomes were evaluated with the following at 6, 12, and 24 months after surgery: arc of motion of the knee, American Knee Society (AKS) score,²⁴ Western Ontario McMaster University Osteoarthritis Index

Table 1 Comparison of Demographics and Preoperative Evaluation Between the Two Groups

	Group A (n = 77) (18.5≤BMI<25)	Group B (n = 41) (BMI<18.5)	P
Age (years)	70.2 ± 5.8	71.3 ± 5.4	0.236
Hip-knee-ankle angle (°, varus)	7.5 ± 5.0	8.2 ± 5.4	0.486
Serum level			
Albumin (g/dL)	4.2 ± 0.6	3.8 ± 0.5	0.020
Hemoglobin (g/dL)	13.7 ± 1.0	12.8 ± 1.5	<0.001
C-reactive protein (mg/L)	2.1 ± 2.1	1.9 ± 2.1	0.615
Total cholesterol (mg/dL)	163.4 ± 26.3	158.3 ± 27.9	0.793
Preoperative clinical score			
Flexion contracture (°)	4.4 ± 5.1	5.5 ± 8.1	0.418
Range of motion (°)	128.7 ± 21.6	125 ± 27.5	0.449
AKS knee score	53.1 ± 21.4	52.1 ± 19.0	0.797
AKS function score	51.9 ± 15.7	56.3 ± 12.4	0.127
WOMAC pain	9.9 ± 4.8	9.4 ± 4.9	0.320
WOMAC stiffness	3.8 ± 2.1	4.1 ± 2.3	0.572
WOMAC function	37.3 ± 15.0	33.4 ± 15.1	0.467
WOMAC total	58.2 ± 22.3	53.1 ± 23.1	0.173
PF scale	21.1 ± 7.2	21.4 ± 7.0	0.237
Quadriceps strength	4.8 ± 0.6	4.5 ± 0.8	0.044
Good (5/5): Fair (4/5)	69(89.6%): 8(10.4%)	31(75.6%): 10(24.4%)	0.044

Note: Data are presented as mean ± standard deviation.

Abbreviations: BMI, body mass index (kg/m²); AKS, American Knee Society; WOMAC, Western Ontario and McMaster Universities; PF, patellofemoral.

scale (WOMAC),^{25,26} and the Kujala patellofemoral score.²⁷

The arc of motion of the knee was represented by maximum flexion and range of motion (ROM), which was calculated by subtracting the degree of flexion contracture from the degree of maximum flexion. An independent investigator used a goniometer to measure flexion contracture and maximum flexion to the nearest 5°, with the patient in the supine position.²⁸ At 24 months after surgery follow-up visits, radiologic outcomes were evaluated such as hip-knee-ankle angle and loosening of implant.

Statistics

All statistical analyses were performed with SPSS version 20 for Windows (SPSS Inc., Chicago, IL, USA), and p values <0.05 were considered statistically significant. Mean and standard deviations were calculated to describe characteristics. Student *t*-test was used for between-group comparison of continuous data. And, Chi-squared test of Fisher exact test was used to compare categorical data. A multivariate linear regression analysis was used to determine whether BMI group impacted postoperative clinical outcomes while controlling for multiple variables.

Results

In all patients, the degree of degenerative osteoarthritis was Kellgren-Lawrence grade III or IV. The mean follow-up period was 2.3 years. Table 1 compares pre- and postoperative clinical data between groups. There was no significant difference in age, hip-knee-ankle (HKA) angle, serum levels of CRP, and total cholesterol between two groups ($p > 0.05$). However, serum levels of albumin and hemoglobin of underweight patients were lower than patients with normal BMI (albumin, 4.2 ± 0.6 vs 3.8 ± 0.5 , $p=0.02$; hemoglobin, 13.7 ± 1.0 vs 12.8 ± 1.5 , $p<0.001$). The manual test of quadriceps strength was better in the normal BMI group (4.8 ± 0.6 vs 4.5 ± 0.8 , $p=0.044$). There was no significant difference in preoperative flexion contracture, ROM of the knee, AKS, WOMAC and PF scores between two groups. Table 2 and Figure 1 show comparison of postoperative clinical outcomes between two groups at 6, 12, and 24 months after surgery. At 6 months after surgery, there was no significant difference in clinical outcomes of two groups. However, postoperative WOMAC pain score (group A, 1.8 ± 1.9 ; group B, 3.4 ± 2.6 , $p=0.02$, effect size $d=0.70$), WOMAC function score (group A, 12.4 ± 8.1 ; group B, 16.5 ± 8.5 , $p=0.012$, effect size $d=0.49$), and PF scales (group A, 26.1 ± 3.6 ; group B, 23.7 ± 4.1 , $p=0.002$, effect size $d=0.62$) were worse in the underweight group at 12 and 24 months after surgery.

Table 2 Comparison of Postoperative Outcomes of TKA Between Two Groups

	Group A (n = 77) (18.5≤BMI<25)	Group B (n = 41) (BMI<18.5)	P
Postoperative 6 months			
Flexion contracture (°)	3.3 ± 3.7	3.2 ± 3.7	0.981
Range of motion (°)	130.6 ± 17.0	130.1 ± 13.4	0.965
AKS knee score	69.9 ± 25.7	76.6 ± 16.8	0.138
AKS function score	71.6 ± 24.3	70.1 ± 19.9	0.732
WOMAC pain	4.9 ± 2.3	4.6 ± 2.2	0.610
WOMAC stiffness	3.2 ± 1.5	2.8 ± 1.5	0.138
WOMAC function	20.3 ± 11.1	20.9 ± 10.9	0.781
WOMAC total	28.6 ± 11.3	28.1 ± 11.9	0.845
PF scale	23.6 ± 11.4	23.1 ± 11.0	0.408
Postoperative 12 months			
Flexion contracture (°)	1.4 ± 1.3	1.1 ± 2.1	0.978
Range of motion (°)	132.4 ± 6.2	131.1 ± 11.7	0.350
AKS knee score	89.6 ± 6.6	87.6 ± 5.2	0.102
AKS function score	86.4 ± 11.8	84.8 ± 10.3	0.408
WOMAC pain	1.9 ± 2.2	3.0 ± 1.8	0.003:
WOMAC stiffness	1.7 ± 1.2	2.1 ± 1.3	0.083
WOMAC function	12.6 ± 5.6	16.2 ± 7.3	0.003:
WOMAC total	16.2 ± 6.4	21.4 ± 7.6	<0.001:
PF scale	25.8 ± 3.0	23.8 ± 2.9	0.001:
Postoperative 24 months			
Flexion contracture (°)	1.2 ± 1.8	0.4 ± 1.4	0.964
Range of motion (°)	133.1 ± 6.1	132.1 ± 12.0	0.186
AKS knee score	91.8 ± 6.7	92.5 ± 6.8	0.978
AKS function score	91.4 ± 12.4	89.2 ± 11.4	0.350
WOMAC pain	1.8 ± 1.9	3.4 ± 2.6	0.020:
WOMAC stiffness	1.6 ± 1.1	1.9 ± 1.4	0.095
WOMAC function	12.4 ± 8.1	16.5 ± 8.5	0.012:
WOMAC total	16.4 ± 10.5	22.1 ± 10.7	0.007:
PF scale	26.1 ± 3.6	23.7 ± 4.1	0.002:
Hip-knee-ankle angle (°, varus)	1.3 ± 2.2	1.7 ± 2.1	0.398
Mechanical alignment outliers	9 (11.7%)	6 (14.6%)	0.425
Early loosening	0 (0%)	0 (0%)	

Notes: Data are presented as mean ± standard deviation. Significance of bold values is $p < 0.05$.

Abbreviations: BMI, body mass index (kg/m^2); AKS, American Knee Society; WOMAC, Western Ontario and McMaster Universities; PF, patellofemoral.

Effect sizes were moderate for these postoperative WOMAC pain scores, WOMAC function scores, and PF scales. No other significant differences were found between groups ($p > 0.05$).

Multivariate linear regression analysis controlling for age, preoperative HKA angle, preoperative serum level of albumin, hemoglobin, total cholesterol, CRP, quadriceps strength, preoperative clinical status (AKS, WOMAC, PF scores) demonstrated that BMI group was significantly associated with postoperative WOMAC and PF scores. Table 3 summarizes the output of the linear regression analysis.

Table 4 summarizes all complications associated with TKA. The two groups did not differ in the rate of postoperative

complications ($p = 0.294$). There were 7 cases of superficial wound problems, including wound dehiscence and superficial wound infection with no organism confirmed; this included 4 cases in the group A ($18.5 \leq \text{BMI} < 25 \text{ kg}/\text{m}^2$), 3 cases in the group B ($\text{BMI} < 18.5 \text{ kg}/\text{m}^2$). Only 1 patient developed deep infection and need revision surgery; this patient was in the group B. 3 cases of peri-operative morbidity occurred in the group A, including 1 cases of hypovolemic shock, 1 cases of deep vein thrombosis, and 1 case of pneumonia. In the group B, 2 case of peri-operative morbidity occurred, including 1 case of hypovolemic shock and 1 case of deep vein thrombosis. No patients in between groups required revision surgery for aseptic failure.

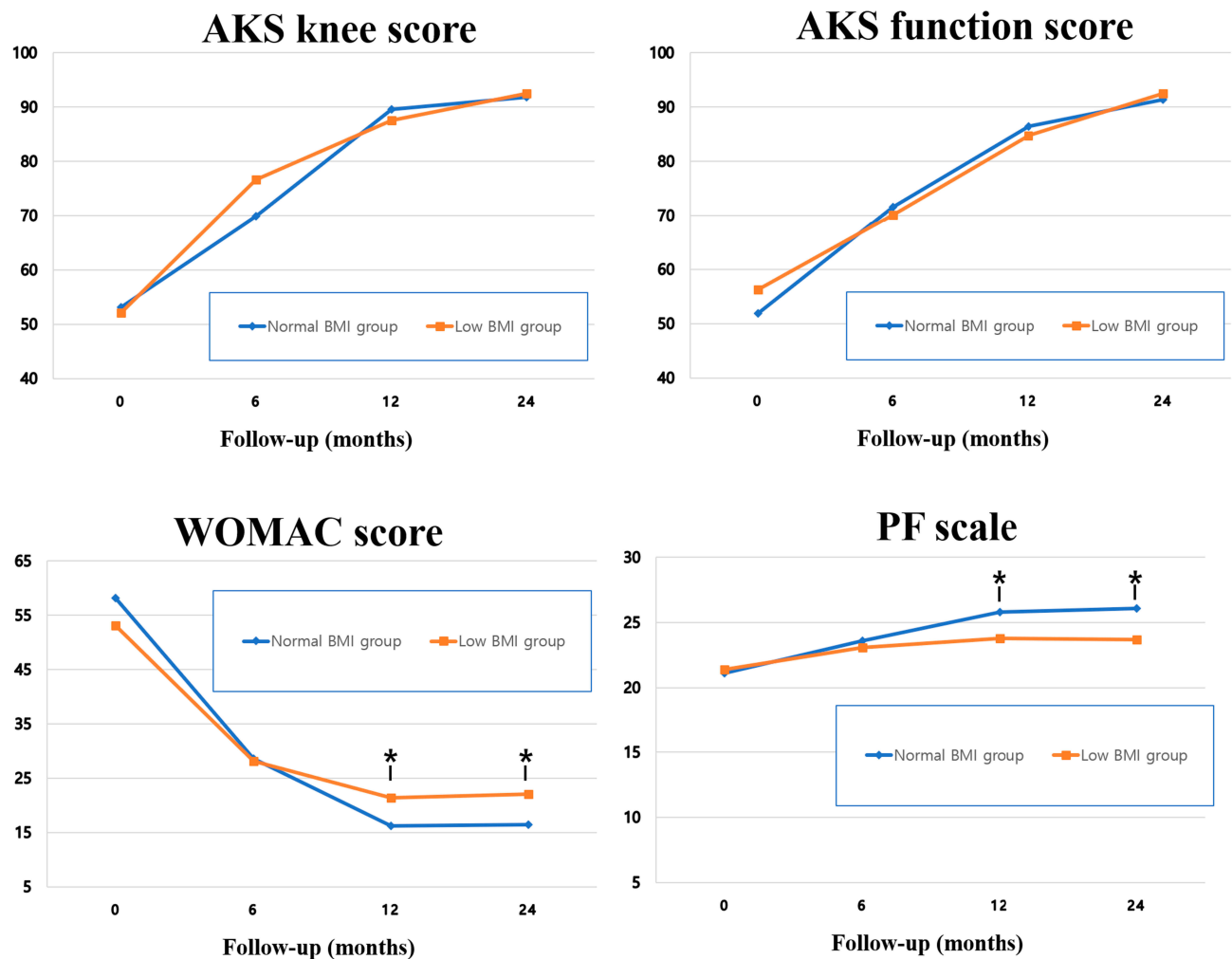


Figure 1 Clinical outcomes based on follow-up periods after total knee arthroplasty in underweight patients and normal body mass index (BMI). The y-axes indicate the AKS knee score, AKS function score, WOMAC score and PF scale, respectively. The x-axes indicate follow-up period (in months) after surgery. Statistically significant in the comparison of two groups is indicated by asterisks, * $p < 0.05$.

Discussion

The current study investigated whether being underweight affects the clinical outcomes of TKA in elderly patients. Since pain and discomfort of patients may still be present at 6 months after surgery, there was no significant difference in clinical outcomes for TKA between BMI groups at that time. However, we discovered that being underweight could influence the early postoperative clinical outcomes of TKA at 2 years after surgery. Although there was no significant difference in early postoperative complications and radiologic outcomes between the study groups, postoperative WOMAC pain score, WOMAC function score, and PF scales at 2 years after surgery reflected worse clinical outcomes in the underweight group than the normal BMI group, and the effect size was moderate.

Numerous studies have focused on the influence of obesity on the morbidity and clinical outcomes of TKA, probably because there are few underweight patients with osteoarthritis in Western countries.^{1,3,6,29-31} However, many patients with osteoarthritis are underweight in Asia, and being underweight in the elderly patients could be predictor of functional disability, so it is also important to determine the clinical outcomes of underweight elderly patients who have TKA. This is the first study to assess the effect of being underweight on clinical and radiologic outcomes of TKA. In many older female patients, being underweight might be associated with sarcopenia or nutritional deficiencies as well as worse cognitive status or depression^{16,21,22} In addition, there have been several studies explaining the underweight of elderly patients with chronic pain, osteoporosis, and the associated frailty, which may be

Table 3 Multivariate Linear Regression Analysis of Postoperative WOMAC Total Score and PF Score Controlling for Age, BMI Group, Preoperative HKA Angle, Preoperative Serum Level of Albumin, Hemoglobin, Total Cholesterol, CRP, Quadriceps Strength, Preoperative Clinical Status (AKS, WOMAC, PF Scores)

	Postoperative WOMAC Total Score		Postoperative PF Score	
	β	P	β	P
Age (years)	0.119	0.224	-0.089	0.350
BMI group	-0.332	0.002	0.298	0.005
Hip-knee-ankle angle	0.082	0.400	-0.038	0.684
Serum level				
Albumin (g/dL)	0.051	0.639	-0.036	0.736
Hemoglobin (g/dL)	0.118	0.249	0.186	0.064
C-reactive protein (mg/L)	0.041	0.420	-0.116	0.227
Total cholesterol (mg/dL)	0.041	0.428	-0.071	0.445
Preoperative clinical score				
AKS knee score	-0.07	0.517	-0.074	0.470
AKS function score	0.037	0.717	0.052	0.622
WOMAC total	-0.016	0.873	-0.099	0.309
PF scale	-0.013	0.905	0.121	0.260
Quadriceps strength	-0.332	0.642	-0.037	0.727

Notes: In multivariate linear regression, underweight group was coded for as the dummy variable and assumed a value of 0. The normal BMI group assumed a value of 1. Significance of bold values is $p < 0.05$.

Table 4 Comparison of Complications in 118 Patients Who Underwent Total Knee Arthroplasty

	Total (n = 118)	Group A (n = 77) (18.5 ≤ BMI < 25)	Group B (n = 41) (BMI < 18.5)	P
Superficial wound problem	7 (5.9%)	4 (5.1%)	3 (7.3%)	
Deep infection	1 (0.8%)	0 (0%)	1 (2.4%)	
Perioperative morbidity	5 (4.2%)	3 (3.9%)	2 (4.8%)	
Need for revision (aseptic)	0 (0%)	0 (0%)	0 (0%)	
Total	13 (11%)	7 (9.1%)	6 (14.6%)	0.370

related to the worse outcomes of TKA.^{15,32} Several studies have shown that patients with severe degenerative osteoarthritis can experience depression and anorexia after TKA due to pain and limitation of knee function, factors that might be closely related to poor nutritional status.^{33,34} Poor nutritional status may affect both peri-operative morbidity and

postoperative recovery of general conditions.³⁵ Low serum levels of albumin and hemoglobin in underweight patients of our study might suggest indirectly poor nutrition status. In addition, there was a mild decrease in quadriceps strength in underweight patients. Since sarcopenia is a risk factor for poor rehabilitation of knee function and postoperative infection after TKA,^{36,37} the decrease of quadriceps strength might cause worse clinical outcomes. However, it is difficult to say that mild decrease in quadriceps strength is the main cause of worse clinical outcome, as it could have resulted from a combination of many factors, such as poor nutrition and frailty. Since we confirmed that underweight elderly patients had worse clinical outcomes after TKA compared to patients with normal BMI, surgeons should be aware that outcomes may not be good when considering TKA for underweight elderly patients. Since being underweight might be associated with sarcopenia and poor nutrition status, additional studies including evaluations of nutritional status or quantified sarcopenia of patients are required.

Fibrosis and inflammation caused by soft tissue impingement and overhang of the implant might cause increased postoperative knee pain and discomfort after TKA.^{38,39} Although we could not clarify the relationship between overhang of the implant or impingement and being underweight, we confirmed that postoperative PF scales associated with anterior knee pain were higher in underweight patients. For these reasons, underweight patients can experience poor clinical outcomes after TKA due to fibrosis and inflammation induced by soft tissue impingement and overhang of the implant. Further studies of this are needed. In addition, although the risk of a common wound complication may be higher in obese patients, the risk of a wound complication might also be high in patients who are so thin that they lack proper soft tissue for sutures. Thus, underweight patients should undergo proper evaluation of the soft tissue around the knee before surgery.

There were several limitations to our study. First, this study was designed as a retrospective cohort study, and the follow-up period was relatively short, with clinical outcomes assessed at 2 to 3 years after surgery. Although we confirmed that early clinical outcomes differed significantly between the groups, longer-term study is needed. This will facilitate comparison with long-term studies of the obesity-related outcomes of TKA. In addition, selection bias may be present because only patients who were followed up for at least 2 years were enrolled. Second, we did not evaluate other risk factors that could affect the clinical outcomes of TKA, such as age, comorbidities and pain in other joints or the back; only BMI was considered. An age- and sex-matched study that excludes other comorbidities and pain could provide more

accurate information on the relationship between being underweight and the clinical outcomes of TKA. In addition, there was no information on comorbidities and frailty diagnosis, which may lead to being underweight. Finally, we evaluated the effect of being underweight in an all-female cohort, and only one type of implant (posterior substituting and fixed bearing type TKA) was used in this study, as we analyzed only primary TKA cases. Using different types of implants (cruciate retaining) may lead to different results. In Asia, women are more likely to undergo TKA than men, and most underweight patients are women. Therefore, the results of this study should be applied with caution to different patient groups or types of implant. Although obese patients are more common than underweight patients, and obesity is generally known to be associated with worse clinical outcomes, complications, and survival rates after TKA, we found that underweight elderly patients with BMI lower than 18.5 kg/m^2 also had worse clinical outcomes. Therefore, orthopedic surgeons should consider the risk of poor outcomes of TKA in underweight elderly patients as well as obese patients.

Conclusion

The complication rate of TKA did not differ significantly between underweight elderly patients with ($<18.5 \text{ kg/m}^2$) and those with normal ($18.5 \text{ kg/m}^2 \leq \text{BMI} < 25 \text{ kg/m}^2$) in the current study. However, postoperative WOMAC pain score, WOMAC function score, and PF scales at 2 years after surgery showed worse clinical outcomes in the underweight group than in the normal BMI group, and the effect size was moderate. Since underweight elderly patients ($<18.5 \text{ kg/m}^2$) could have worse clinical outcomes after TKA, orthopedic surgeons performing TKA in underweight elderly patients should use caution to ensure appropriate preoperative evaluation and careful intraoperative procedures.

Abbreviations

BMI, Body Mass Index; TKA, Total Knee Arthroplasty; AKS score, American Knee Society score; WOMAC score, Western Ontario and McMaster University score; PF scale, Patellofemoral scale; WHO, World Health Organization; ROM, Range of Motion; HKA angle, hip-knee-ankle angle; CRP, C-reactive protein.

Data Sharing Statement

The datasets generated and/or analyzed during the current study that involve patient data are not publicly available because this was not established, nor would it have been accepted, as part of the ethics application.

Ethics and Consent Statement

This retrospective study was approved by the Institutional Review Board of Severance Hospital (date of approval December 31, 2018; IRB number 4-2018-1055). Since this study was a retrospective comparative study, informed consent was waived by the ethics committee. All patient data were anonymously analyzed. Each author certifies that his institution approved the human protocol for this investigation and that all investigations were conducted in conformity with ethical principles of research.

Disclosure

The authors report no funding and no conflicts of interest in this work.

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